PSYCHE.

RECENT STUDIES IN INSECT ANATOMY.*

THIRD ANNUAL ADDRESS OF THE PRESIDENT.

In the annual address expected from the chair of the Cambridge Entomological club, your first President discussed the then recent contributions to our knowledge of the life-history of insects, and last year some of the phenomena of their geographical distribution were brought to your notice; a third side of entomological study fortunately remains for me, and so — simply as a recorder, not as a critic — I will endeavor to lay before you tonight a brief review of the works relating to insect anatomy and physiology which have been published during the past two years. As this could not have been attempted, without the aid of Prof. Carus' Zoologischer Anzeiger, let me join in the paean which grateful zoologists raise to the editor and publisher of this invaluable record of zoological progress.[1]

We find very few general works, as one may suppose, to be noticed. The concluding part of Dr. Graber's useful manual "Die Insecten," has just appeared. It contains the chapters on embryology and development, and as the first general sketch of the subject, its publication is certainly epoch-making. Mr. Emerton's "Structure and Habits of Spiders" contains much on the anatomy and development of these animals, and, with its numerous original figures, will be of great service to general students.

Mr. Maurice Girard[2] has published a work on bees, which I have not yet seen. And this is also the case with Dr. H. Grenacher's large work on the structure of the arthopod eye.[3]

The first annual report of the U. S. Entomological Commission contains a general sketch of the anatomy of *Caloptenus*, by Dr. Packard, the most important part of which is the description of the respiratory system, with its tracheae and air-sacs. There is also a section[4] on the histology of the digestive tract, by Dr. C. S. Minot. Previously unnoticed structures, in the shape

[1] After much of this address was written, the record by Mr. Frank Crisp in the Monthly Journ. Royal Micros. Society came to my notice, and proved useful, as will be seen, in many cases.

[2] Les Abeilles, organs et functions, etc. Paris, Baillière, Dec. 1878. 288 p., 1 pl., 30 figs.

[3] Untersuch. u. d. Sehorgan der Arthropoden. Göttingen, 1879.

[4] See also Dr. Minot's article, Amer. Nat., (June 1878,) v. 12, p. 339.

of twelve longitudinal, forward projecting, folds on the border between the stomach and ileum, are described.

Of the papers on the general anatomy of groups or species, is one of considerable length by Dr. Ernst Voges,[5] on the *Julidae*, the greater part being a description of species, particularly, however, in respect to the male genital armature. There is also a general description of the dermal skeleton, with its muscles, of the tracheal system, and of the scent glands; the section on the tracheal system being the most important. Voges regards the mouths of the tracheae in the "stigmatic pouches," as the morphological stigmata; the pouches themselves being simple infoldings of the derm, carrying the true stigmata within the body. The scent glands are retort-shaped bodies, the necks of which open, of course, into "foramina repugnatoria," and are provided with an automatic plug, the mouth being opened by the contraction of the muscle appended to each gland.

In a later note[6] Dr. Voges describes the tracheal system of Glomeris, which seems to approach that of the hexapods, as there is no stigmatic sac, but true stigmata which open externally, leading into short tubes (probably modified tracheal trunks), which bifurcate, their forks giving rise in turn to furcating tracheae. There is, however, no tracheal anastomosis. The stigmata are armed against the entrance of impurities by an edging of numerous thorn-like structures. It should be remembered that the tubes have points for the insertion special muscles, like the stigmatic sacs of *Julus*.

[5] Zeitschr. wiss. Zool. v. 31, p. 127.

[6] Carus' Zool. Anzeig., v. 1, p. 361.

Mr. S. Sograff sums up his studies on certain Chilopods in a short note in Carus' Zool. Anzeiger (v. 2, p. 16). Among the points referred to may be mentioned the following: The tracheae resemble those of lepidopterous larvae, and are provided with a simple, though very peculiar stigmatic closing apparatus. The brain consists of fibres and of cells of two sorts, the smaller of which recall those of hexapods. The form of the brain depends on the number of eyes and length of body. The longer a chilopod is, the fewer eyes, and the smaller optic lobes, consequently. The latter are totally wanting in *Himantarium*. The structure of the eye closely approaches that of larval insects. The ovaries are much like those of spiders; the nearly ripe eggs are clothed with small, probably epithelial, cells. The receptaculum seminis shows a distinct muscular and epithelial wall. The testes are filled with large, quadrangular big-nucleated, mother cells, which probably arise from the epithelium of the thin, upper part. The walls of the sperm-reservoirs have an epithelial, and a delicate reticulate muscular, layer.

Glands are very numerous. The poison glands consist of a stout chitinous duct, whose walls are pierced with very many chitinous tubelets which end in pear-shaped glands. The whole glandular system is clothed with a muscular *rete*, as Leydig has already shown to be the case with the nervous system.

The poison glands of centipedes have been, however, previously described by Mr. Jules Macleod.[7] According to the latter writer, the glands lie in the terminal joint

[7] Bull. Acad. Roy. Belg., v. 44, no. 6.

of the forceps, extending into the distal half of the basal joint. Each gland is in the shape of a long sac, in the middle of which runs a chitinous excretory tube strengthened by a spiral fibre, trachea-like. Minute perforated cylinders cover the outside of the tube, to which are attached the very long glandular cells, radiating out from the central tube. The gland is enveloped exteriorly by a *tunica propria*, which is inflected along one side and probably reaches, and is attached to, the central tube, thus making a long narrow furrow along the gland. The latter is remarkable for the want of tracheae. The central tube opens very obliquely on the upper surface of the forceps just behind the point, forming a minute, long-oval cleft.

Mr. J. A. Ryder's papers[8] on *Eurypauropus*, though not anatomical, deserve mention here as recording the discovery of new genus of Pauropods. *Eurypauropus* superficially differs from *Pauropus*, as does *Polydesmus* from *Julus*, that is, it is a flattened and obtected form. There are only six actual segments, instead of ten as in *Pauropus*, but like the latter nine pairs of legs. Eyes are wanting. Ryder wrongly (as he has since recognized) figures the legs as terminating with two claws, instead of one. The mouth parts, moreover, seem to me to project backwards instead of forward as represented by Ryder. The larvae are very odd, and apparently composed of only three segments. As in *Pauropus*, they are hexapod.

Any addition to our knowledge of that remarkable form *Peripatus*, which we must recognize as a tracheate arthropod, and which can hardly fail to throw important light on the whole group, is also to be gladly recorded. Mr. F. M. Balfour has just published a short note[9] on *Peripatus capensis*. Organs, apparently to be recognized as segmental, are found "at the bases of the feet in two lateral divisions of the body-cavity, shut off from the central median division by longitudinal septa of transverse muscles." These consist of: a dilated vesicle opening at the base of the feet; a coiled glandular tube connected with this and subdivided again into several minor divisions; a short terminal portion opening into the body cavity. These segmental organs approach more nearly those of the leech. There are besides two glandular bodies.

Balfour finds a suboesophageal ganglion, and distinct ventral ganglionic swellings for each pair of feet. In the nervous system there is, therefore, more resemblance to the normal articulate nerve chain than has been supposed to exist. There are traces also of a sympathetic system.

The organ doubtfully described by Moseley as a fat body, turns out to be a glandular tube, opening by a non-glandular duct into the mouth. This Balfour regards as homologous with the salivary glands, and thus of course we find another arthropodan affinity in *Peripatus*.

Mr. A. Croneberg gives an abstract[10] of a paper in the Russian language, on the structure of three genera of *Hydrachnida* (*Hydrachna*, *Eylais*, *Nesaea*). The mouth parts, the genital, and digestive organs are

[8] Proc. Acad. Nat. Sci. Phila., 1879, p. 139, 164. Amer. Nat., v. 13, p. 603.

[9] Quart. Journ. Micr. Sci., v. 19, p. 431; also Carus' Anzeig., v. 2, p. 332.

[10] Carus' Zool. Anz., v. 1, p. 315. Croneberg has also published a paper (Bull. Soc. Imp. Nat. Moscow, 1879, No. 2, 234), not yet come to hand, on the structure of *Trombidium*.

described. The latter consist of a large stomach with a variable number of coeca, — 5 in *Nesaea*, 11 in *Hydrachna*, 34 in Eylais. All these coeca communicate with each other, and are clothed with large, brown cells, numbers of which also occur in the stomach, and represent the liver. The excretory organs are reduced in *Hydrachna* to a single median sac, wider anteriorly. In *Nesaea* it divides into four short branches, but it is more complex in *Eylais*. The terminal portion in all tends downward and runs direct to the anus. There is no rectum, the stomach ending blindly, according to Croneberg. A sort of fat body is found about the digestive organs. There are three sets of oral glands in *Eylais* which open by a common duct into the mouth.

A paper [11] by the late Dr. Hermann Lebert, Die Spinnen der Schweiz, Bau und Leben, &c., I have not been able to see.

Dr. Batelli [12] has studied the anatomy of the larva of *Eristalis tenax*. The external tube of the long tail is regarded as a modified segment, which is shown by the presence of the lateral papillae, each with its long hair, as occurs in the other body segments. The retraction of the internal tube is by two muscles inserted at its superior extremity, where there are some gigantic cells with large nuclei, having in the interior, as a product of elaboration, a long twisted filament. Connected with the two tracheae are two air sacs almost the length of the body. The digestive apparatus has in its vestibule two chitinous plates. In the pharynx, besides the two jaws, are eight peculiar beards, consisting of two series of divaricated barbules. The salivary ducts are lined with a spiral thread, as is often the case. The chylific stomach is preceded by four ventricular glands, and there are four Malpighian tubes. The anal glands contain a great quantity of urates, and are composed of a straight part and another folded back. Besides the supra- and sub- oesophageal ganglia are two intermediate ones connected by means of a peduncle to the lateral commisure. The following ganglia are united.

Mr. Carl Gissler [13] has described the anatomy of the once rare *Amblychilacylindriformis*, and figures parts of the nervous, digestive, and reproductive systems. No new results are to be noted.

Turning now to special papers on the anatomy of particular organs or systems, we may first notice several on the dermal skeleton and its appendages.

Led by Darwin's difficulty in reconciling the great difference between the worker ants and the sexual individuals, Dr. H. Dewitz [14] has studied the development of the legs, and especially of the wings in *Formica rufa*. His results, together with some additional observations on the development of the wings in lepidoptera, are best summed up by using nearly his own language: "The ant-workers, like the

[11] Neu Denkschr. d. allg. Schweiz. Ges. f. Naturw., v. 28. Also separate, by Friedländer und Sohn.

[12] Soc. Toscan. di Sci. Nat., Proc. Verb., Nov. 1878. Shortened from notice in Ann. Mag. Nat. Hist., 5, v. 3, p. 94.

[13] Psyche, v. 2, p. 233.

[14] Zeitschr. wiss. Zool. v. 30, Suppl., p. 78; supplementary note, *ibid*, v. 31, p. 25; also Sitzungsb. Ges. Nat, Berlin, 1878, 122.

males and females, possess in their young stages small, yet identically formed wing-buds ["imaginal discs"] which retrograde during further growth.

"The thoracic appendages of ants make their first appearance in the young larva, as disc-shaped thickenings of the hypoderm, which divide into a core (leg or wing), and an envelope, with an external opening (covered, of course, by the chitin layer). The envelope grows into a sac or pocket-shaped fold within the body cavity; the core or bud into the respective leg or wing. During the transition to the pupal stage the sac is turned inside out, or rather the opening which existed from the first, becomes enlarged and the appendage is thrust forth.

"The developing leg or wing of the ant and bee casts its skin while yet in the larval stage; so that, in respect to undergoing a moult, there is not the least difference between the postembryonal formed appendages of insects with a perfect or imperfect metamorphosis (e. g., leg and wing of the ant, wing and ovipositor of the grasshopper); the difference being simply that in insects with perfect metamorphosis the new forming appendage lies generally hidden in infoldings of the hypoderm, making its first appearance outwardly during pupation; while in insects with imperfect metamorphosis, this occurs at the beginning.

"Likewise the formation of the lepidopterous wing, and, according to my view, of the appendages of all insects, starts from the hypoderm, although perhaps the entering tracheae, nerves, &c., effect the internal formation of the appendage.

"The great difference between ant workers and females is not brought about by different treatment of the larvae or eggs by the mature workers, but while yet in the maternal body the egg receives the imprint of its future destination."

Dewitz farther studied the mode of origin of the thoracic thorns in *Myrmica*, which grow directly out of the hypodermis, thus behaving very differently from the locomotive appendages. A section on the difficulty of accounting for the inheritance of worker characters, which Dewitz cannot help to clear up, concludes this interesting paper.

Dr. Dewitz also in a short note [15] records a case of malformation in which five joints of one of the hind legs protruded through the larval skin of an ant (*Atta insularis*) nearly ready to pupate. Dewitz does not, however, think that this is simply a case of incompleted moult, but believes that the leg from the first, instead of lying in the hypodermic infolded sack, grew outwards and, being unable to separate the hypoderm from the chitinous layer, pierced the latter before it became much hardened.

A paper by Mr. Antoine Simon, on the Hautskelet der arthrogastrischen Arachniden [16] I have not seen.

Schneider, in a paper [17] of nearly sixty pages in length, describes the different forms of scales found on the different parts of the body and wings of the lepidoptera. Two plates illustrate these forms, and a diagram of a lepidopter, showing the character of the scales on different parts in the *Rhopalocera* and *Heterocera*, is also given.

Mr. Joseph Beck [18] adds a little note to his studies on the scales of insects. In a

[15] Carus' Zool. Anz., v. 2, p. 135.

[16] Salzburg, Verf., 1878.

[17] Zeitschr. ges. Naturwiss., v. 51, p. 1.

[18] Journ. Roy. Micr. Soc., v. 2, p. 810.

species of *Mormo* he has found scales showing under a 1-5 "notes of exclamation" like Thysanouran scales, while with a 1-10 the real ribbed structure of the scale is evident. It is also stated that corrugations of lepidopterous scales are invariably found on the under side only. Just the opposite is maintained by Dr. H. Burmeister,[19] who also believes that there is no internal membrane. The striae are due to filaments elevated on the inner side of the upper membrane. In the large scales of Castnia they do not traverse the scale, but terminate free. The lower membrane has a different internal structure showing a great number of small irregular transverse lines.

Haller[20] figures and describes peculiar forms found in the terminal hair brushes of *Polyxenus*. These are transparent, hooked at the end, which has three or four slender clubbed processes directed backwards and lying in the same plane. The sides of the hair are barbed with forward directed points. These hairs are surrounded with shorter club shaped ones. There are also larger double comb-like hairs, the teeth of which point forwards.

Ignorant of Hick's long since published paper,[21] Haller[22] also describes briefly the sucking hairs on the tarsus of male water beetles (*Dytiscus*); nothing new is reported.

Dr. Ph. Bertkau has described[23] an interesting scent apparatus on the last pair of legs in the male of *Hepialus hecta*, L. In this moth the posterior tarsi are aborted, and the tibiae are large and club-shaped, their interior being filled with long glands which each open in a pore. A long hair covers each pore, and on the inside of the tibiae these hairs form a thick brush. The first abdominal segment, moreover, has beneath two pockets, formed by an infolding of delicate skin, the margins of which are also provided with long hairs. In rest the moth keeps the hinder tibiae in these pockets, the long hairs on both effectually preventing the escape of the ethereal oil secreted by the tibial glands, which has a pleasant aromatic odor. This of course recalls the scent apparatus on butterfly wings described by Fritz Müller, and must serve as an attraction to the opposite sex.

Mr. Brunner von Wattenwyl[24] has found a peculiar organ on the hind femora of the *Acrididae*. In the furrow on the under side, into which the tibia fits, about one fourth from the base, is a small wart-shaped elevation, open in the centre, where there is a soft pad, sometimes projecting like a blunt tubercle. The raised margin of the elevation is on the basal side beset with some delicate white hairs. The pad, which has a glandular appearance, is always white or gray. It is found only in the jumping tribes, but occurs both in chirping and dumb species. No suggestion as to its function is offered.

Messrs. Perez[25] and Jousset De Bellesme[26] discuss the nature of buzzing in insects. True buzzing is the sound emitted by rapid wing vibrations (exceeding 80). The hum of the hawk-moths is simply the

[19] Descr. Phys., Republ. Argentine, v. 5, p. 21. See notice Journ. Roy. Micr. Soc., v. 2, p. 866.

[20] Arch. f. Naturg., v. 44, p. 99.

[21] Linn. Trans., v. 22, p. 147, 383.

[22] Arch. Naturg., v. 44, p. 97.

[23] Katter's Ent. Nachr., No. 17, 223.

[24] Verhandl. Zool.-Bot. Ges. Wien.

[25] Comptes rend., v. 87.

[26] Ibid., p. 535.

friction of the wing against the air. Hymenoptera and diptera are the only true buzzing insects, and according to De Bellesme produce two sounds, a grave and a sharp. The latter is produced by the vibrations of the thorax. The thoracic stigmata may be closed without destroying the humming power, thus disproving Landois's theory.

Mr. Perez [27] in a supplementary communication does not agree with Mr. De Bellesme in thinking that a conical movement of the thorax (whatever that may be) can produce a sound, because on fixing the animal with a pin the movements are very attenuated, without the movements of the wings and the buzzing being destroyed, or even weakened.[28]

Mr. Carl Gissler describes [29] the repugnatorial glands of *Eleodes* as two reddish-brown, semi-bilobed pieces in the form of a Y, extending from the base of the last, to the middle of the second segment, a length of about 6.5 mm. He did not succeed in recognizing the nature of the secretion.

The balancers in the diptera have been studied by Messrs. J. De Bellesme [30] and Rob. Desvoidy,[31] but I have not been able to see the paper of either.

Dr. W. Breitenbach [32] describes the peculiar appendages on the proboscis of the lepidoptera, which he thinks enable the insect to pierce the tissues of flowers, &c., for honey or other juices. The orange-sucking moth, *Ophideres fullonica*, the structure of whose proboscis was first made known by Mr. Francis Darwin, is of course the typical example of this power in the lepidoptera, but Breitenbach shows that many other genera of butterflies and moths are armed, though less formidably, for similar purposes. These appendages are of course confined to the end of the proboscis, and are modifications of simple hair structures, such as are found on the basal portion, consisting of the hair itself and the annular basal ridge from which it grows. This ring becomes lengthened into a cylindrical body, still having the terminal hair, which, however, becomes much reduced — often to a simple papilla. The end of the cylinder is then armed with teeth, or its sides develop ribs or plates, or sometimes several rows of teeth. Indeed we find a large number of patterns connected by more or less numerous stages of development, and which Breitenbach believes may furnish useful systematic characters. Every step in the evolution of the simple hair to the perfected barb on the proboscis of Ophideres may be traced. The author seeks to reconcile the view that these structures are taste organs, by suggesting that this function may belong to the simple hairs, some of which, however, have been developed by natural selection into boring organs.[33]

Mr. Jules Künckel [34] has examined the termination of the nerves in the proboscis

[27] Rev. Internat. Soc., v. 3, (79), p. 281.

[28] Quoted from Journ. Roy. Micr. Soc., v. 2, p. 408.

[29] Psyche, v. 2, p. 209.

[30] Balanciers chez les Ins. dipt. 96 pp. Paris, Germar Bailliere & Cie.

[31] Bull. sci. Dépmt. du Nord, 2 s., v. 1, p. 217.

[32] Arch. Mikr. Anat., v. 15, p. 8, and Katter's Entom. Nachr., v. 5, p. 238.

[33] See also a note in Carus' Zool. Anzeig., v. 2, p. 427.

[34] Assoc. Franç. Avanc. Sci. (1878), 771. From notice in Journ. Roy. Micr. Soc., v. 2, p. 865.

of diptera. The two terminal flaps of the proboscis represent the labial palpi. The trachea-like internal structures are not real tracheae, but simply supports of the flaps. Parallel to the large trunk of these false tracheae, is the labial nerve, which soon divides into two parts, and sends a multitude of ramifications to the periphery and inner surface of the flaps. The former terminate in the marginal, well developed, hairs; the latter in the rudimentary hairs of the inner surface, which are reduced to a minute chitinous cylinder. The nerve filament that goes to a hair ends in the base of the latter; but in the rudimentary hairs the filament traversing the cylinder projects beyond. These are probably gustatory, and the former tactile.

Mr. V. T. Chambers[35] describes the structure of the tongue in some hymenoptera. In the *Apidae* he decides it is a sucking organ, but not in the *Andrenidae*. The honey in the former passes through a hollow colorless tube open at the apex, with a smallest diameter of 1-20th of a millimetre; but in the latter this tube is imperforate at the apex. Mr. J. D. Hyatt also discusses[36] the same subject, differing, however, from Mr. Chambers, in believing the colorless rod to be open along the median ventral line, and applied to the ventral, instead of dorsal, internal aspect of the tongue itself. Both writers are unfortunately unacquainted with the recent descriptions of Wollf and Graber.

Mr. Chatin compares[37] the labium in the orthoptera with the maxilla, and finds that the pieces of the latter have homologues in the former. *Locusta viridissima* is taken as an example.

I have myself attempted[38] to describe the structure of the head, and more particularly of the maxillae, in the *Psocidae*. The latter are remarkable for their fork-like appendage, the morphology of which is not clear. Supposed salivary receptacles are also described.

The most valuable paper relating to the digestive system is Dr. E. Schindler's monograph[39] on the Malpighian vessels. After the usual prefatory history of the conflicting views as to their function, Dr. Schindler describes these organs in detail in the orthoptera. Histologically, by the way, each tube shows (1) a serous membrane, (2) a delicate *tunica propria*, (3) the glandular epithelium, and sometimes (4) an *intima* with pores. The author could not find the vessels in *Thysanoura*; in *Lepisma*, however, he believes there are eight arising from the posterior end of the chylific stomach. In *Mantis* they are inserted at the end of the first third of the small intestine. The Malpighian tubes in the *Gryllidae*, as well known, are remarkable in the possession of a common excretory duct, which Dr. Schindler finds has a peculiar muscular envelope. The terminal appendages, imperfectly described by Sirodot, are shown to belong to the connective tissues, and have not in any way an excretory function. Heidenhain's sulphindigotate experiment was tried with *Gryllotalpa* and *Locusta* (by injections of course), and the Malpighian vessels were found to act just like the mammalian urin-

[35] Journ. Cincinnati Soc. Nat. Hist., v. 1, p. 40, 161.

[36] Amer. Quart. Micr. Journ., v. 1, p. 287.

[37] Comptes rend., v. 87.

[38] Proc. Bost. Soc. Nat. Hist., v. 19, p. 291; also Psyche, v. 2, No. 43.

[39] Zeitschr. wiss. Zoologie, v. 30, p. 587.

ary tubules. The gradual passage of the sulphindigotate could be traced through the excretory cells. The yellow and white forms of tubes are regarded as identical in function, and moreover the former are probably only a younger stage of the white tubes.

The pseudoneuroptera are very like the orthoptera in the Malpighian vessels, and contract into the genuine neuroptera, when the number of tubes is only six or eight.

Leaving the orthoptera, the other groups are then briefly treated.

Dr. Schindler doubts Dr. Mark's opinion that the vessels are ever solid in *Lecanium*, *Aspidiotus*, &c., as he has never failed to find a lumen in the case of every insect examined, although the genera in question do not appear to have been among the number.

The diptera are found to present several points of interest. The assertion that *Culex* and *Psychoda* have five Malpighian vessels is confirmed, and these genera are thus the only known exceptions among insects to the rule that the number of vessels is two or some multiple. A singular difference was found between *Eristalis tenax* and *E. florens*. The former shows the normal form of epithelial cells, while they are convex or even conical externally in the latter, giving the vessels a sort of gnarled surface, in the little hillocks of which the nucleus lies, drawing to it the granular contents of the cell, and leaving the inner portion pellucid. In *Sarcophaga carnaria* cells in different regions of a tube were seen multiplying by division and by proliferation.

In the fan-winged moths six vessels were found, as in other lepidoptera, contrary to Suckow's affirmation that they have only four. In a noctuid pupa all six vessels were found opening into a simple duct, — probably a malformation. Important observations on the sympathetic nerve supply of the Malpighian vessels was made in *Euprepia*, to which I can only refer.

Dr. Schindler declares confidently that his researches must forever settle all dispute about the function of the Malpighian vessels. They are certainly urinary organs.

The opposite view is, nevertheless, maintained by Dr. H. Simroth, in a paper on the digestive system of the larva of *Osmoderma eremita*,[40] who believes that, in this case at least, these vessels must be hepatic. First, because they open into the digestive tract on the same level with the posterior coecal appendages which exist in this larva, and the presence, moreover, of a gutter-like arrangement, which Simroth believes must lead their secretion even farther forward in the digestive tract. Second, he has not found urinary contents; finally, because digestion must take place posteriorly to their insertion. We have such conclusive evidence in many cases of the renal nature of the Malpighian vessels that it is hard to believe that we have a real exception here; and if we concede to such an exception, the absence of renal organs must still be explained. Simroth's arguments at least show the necessity of farther study of the action of the complicated parts in this insect, which Simroth carefully describes, but of which it would be hard to give an intelligible account here.

Mr. Felix Plateau continues his re-

[40] Giebel's Zeitschr. ges. Naturwiss., v. 51, p. 493.

searches on the digestive organs, by a paper [41] on this system in the myriapods. The digestive tube shows three divisions: an oral, middle, and terminal. The first may be short and broad (*Julus*), or long and narrow (*Geophilus*). The epithelial layer is sometimes wanting, and the cuticle has sometimes projecting points. The terminal division is often short, but in some forms (*Glomeris*) becomes very long, and is coiled. There is a pair of salivary glands, and one or two pairs of Malpighian tubes; the latter open at the end of the mid-gut, and seem to be urinary organs.

Dr. Forel [42] describes the gizzard in the different groups of ants, claiming its importance, and the importance of a general knowledge of internal as well as external anatomy, for natural classification. The gizzard in the ants is composed of three divisions, the second of which is a simple slender tube, the cylindrical protrusion of which into the interior of the stomach form the third division, which differs only in this position in the stomach from the second. The cuticular intima of these divisions turns on itself at the opening of the third, into the stomach, and thus covers it externally; but on reaching the gastric cells of the stomach it vanishes, leaving the stomach without any intima, — differing from the rest of the digestive tract in this respect. The middle or cylindrical division never varies in the different genera except as to length, but it disappears entirely in some groups. Anteriorly the cylindrical part expands suddenly into the anterior division — the true gizzard — which in contrast to the former, varies in the different groups. This division consists of two parts, a globular "bowl" and a cylindrical "calyx," the latter the anterior. In these the interior cuticle is thrown into four large longitudinal folds, so that the lumen is X-shaped in cross section. Between the "bowl" and the "calyx" there is a valvular apparatus of four pieces, corresponding to the fold. Four powerful longitudinal muscles lie in the fold. The structure of this anterior division, as seen from the description just given, is too complex to be understood properly without reference to the figures. The forms occuring in different genera are described, and their value for classification is pointed out.

Mr. V. Liénard has published [43] some "Recherches sur la structure de l'appareil digestif des Mygales et des Néphiles," which have not yet reached us. A note in Carus' Anzeiger states as a result, "There is no glandular organ attached to the cephalothoracic portion of the intestine; the branches of the latter ramify more and more as the size of the animal increases."

Mr. L. Joulin [44] shows graphically the changes in weight undergone by a lepidopter, from birth to death, by a curve, the ordinates of which represent the weight, and the abscissae the age, of an individual. The curve is seen to ascend with great rapidity, till the larva ceases to eat, then falls as suddenly till nearly half reduced, when it declines gently during the last pupal days, suddenly falling at exclusion, — the result of the lost weight of cast skin, &c. — from which time there is another grad-

[41] Mém. Acad. Roy. Sci. Belg., v. 42.

[42] Bull. Soc. Vaudoise des Sci. nat., v. 15, p. 337.

[43] Bull. Acad. Belg., v. 46, p. 698–706. There is also a "Rapport sur ce travail," Ibid., p. 586–7, by M. F. Plateau.

[44] Comptes rendus, v. 87, p. 334.

ual fall till death, varied of course in feeding imagos by slight rises and falls.

Prof. Engelmann communicates[45] some observations made by Van Lidth de Jeude, on the silk glands of the silk worm. Each gland beyond the common duct, consists of a very fine duct, a stout, little contorted, intermediate division (so-called reservoir), and a long much contorted final division; each part has a delicate *membrana propria*, and an epithelial layer. The inner surface of the duct and beginning of the next part have also a firm cuticle. Numerous fine tracheae penetrate the epithelium of the middle and end divisions, as do also accompanying on independent nerve fibres. The epithelial cells are diverse in the three portions; two cells only appear in a cross section (more in *Cossus*). The nature of the protoplasm of the cells of each division is further described at length. The silk-gum and the yellow coloring matter were found to be secreted by the middle division. The specific peculiarities of the silk are developed after the union of the two ducts. Silk spun under water was found not to differ from that spun in the air, thus precluding the idea that drying is necessary.

Concerning the nervous system may first be mentioned the papers of Dr. Edouard Brandt,[46] who has undertaken a most comprehensive series of studies on this subject, 1032 species of hymenoptera, coleoptera, hemiptera, lepidoptera, and diptera having been examined. The results show: 1. In some forms, as in *Stylops*, the suboesophageal ganglion fuses with the next posterior. 2. "Convolutions" of the brain occur in all; but (3) vary in different individuals of the same species, and are less developed in the males of the social hymenoptera than in the females and workers. 4. A connection between the development of the instincts and that of the brain hemispheres. 5. The labrum nerves arise from the oesophageal nerve-ring. 6. When two thoracic ganglia exist, the first corresponds to the first or the first two larval ganglia; the second to the one or two thoracic and one abdominal ganglia. 7. The number of ganglia may vary in the same species, e. g., bees and wasps. 8. The penultimate ganglion may be compound instead of the ultimate one. 9. *Bombus* and *Tenthredo* have a thoracic sympathetic system like that of the abdomen. 10. The resolution of one larval ganglion into a number in the adult may occur, as in *Volucella*. 11. In cases of a single ganglion in the thorax of hemiptera, this corresponds to the last two thoracic and all the abdominal ganglia. 12. Lepidoptera have four abdominal and either two or three thoracic ganglia.

Mr. N. M. Wagner[47] points out the supra-oesophageal ganglion as the seat of almost all the functions of the cerebral hemispheres of the vertebrates, and it, in correlation, has a more complex structure than the succeeding ganglia, though formed on the same plan. Nerve cells occupy the periphery, and fibres the interior; towards the centre are three groups of small cells one above the other, and connected by a

[45] Carus' Zool. Anzeig., v. 1, p. 100. Original in Onderzock. Phys. Labr. Utrecht. 3 R. v. 2, p. 115.

[46] I have not seen the original papers in the Hor. Soc. Ent. Ross., v. 14 and 15. My information is taken from the Journ. Roy. Micr. Soc., v. 2, p. 863. See also Comptes Rend., v. 89, p. 475.

[47] Comptes rend., 1879, p. 378. Ann. Mag. Nat. Hist., Nov. 1879, p. 398.

large number of fibres. The front group is intimately connected with the convolutions. Intercrossing of fibres occurs in each optic lobe, coordinating the vision of the components of each eye, but there is no intercrossing between those of opposite eyes.

Dr. J. H. L. Flögel [48] makes the most important contribution yet given to the knowledge of the internal structure of the insect brain. He has made consecutive sections of the brains of very many species, and the paper is accompanied by a dozen selected photographs from these preparations. In the cockroach, for example, he succeeds in making 60-80 transverse, and in one case even 350 longitudinal, sections. This insect was unexpectedly found to have a remarkable brain development, perfectly comparable with that of the higher hymenoptera. The most important parts of the brain are those forming a sort of interior framework, on which the rest of the brain is seemingly laid. Dr. Flögel proposes permanent names for the different parts of this framework, and finds that, starting with *Blatta*, the parts can be traced upwards through the brain of the hymenoptera, and downwards through the other orders.

Some few of the facts given may be here mentioned. The wasps have a brain, at one end of the series, further removed from that of the ants and bees, than is the latter from *Blatta*. The saw flies stand lowest of the hymenoptera in the scale, while the ichneumons approach the ants. In the lepidoptera, coleoptera, and indeed the other groups in general, the brain is simpler, although it can be easily homologized with the *Blatta* type. In caterpillars some parts are absent or very small, and easily overlooked, and the optical lobes of the imago are, moreover, drawn into the interior of the larval brain. Flögel emphasizes three points: the constant occurence of that part of the framework which he calls the "central body," in the adult, while it is almost obsolete in the lepidopterous larva, but not in the hymenopterous; the size of the *lobus olfactorius* in insects with small antennae, but with evidently great olfactory powers, proves, Flögel believes, that the antennae are the seat of this sense. That they are not auditory organs appears from the fact that where these are elsewhere recognizable, as in the orthoptera, they are not connected with any marked brain centre, like the olfactory lobes. Thirdly, although the so-called framework forms the principal part of the brain, there is absolutely no connection of its fibres with the other parts of the brain to be found, — a quite inexplicable fact. A table illustrating the relations between the brains of different insects is appended to the paper.

Another very valuable contribution to this same subject is Mr. E. T. Newton's paper [49] on the brain of the cockroach; his results, reached without previous knowledge of Dr. Flögel's paper, agree substantially with those of this author. For still further permanence of cerebral nomenclature, Mr. Newton latinizes Flögel's names, and in one or two cases proposes different ones, for various reasons. The clearest figures yet given illustrate the external aspect of the brain *en face* and in profile, while the figures of a model of the internal structures are very useful as a help to interpret the sectional views. A detailed de-

[48] Zeitschr. wiss. Zool., v. 30, Suppl., p. 556.

[49] Quart. Journ. Micr. Sci., v. 19, p. 340.

scription of a number of the latter is given, with good figures. Like Flögel, Newton was unable to find the connection of the internal "framework" with other parts of the nervous system.

Dr. E. Berger has a memoir,[50] which I have not been able to see, on the structure of the brain and retina in the arthropods. It is, however, noticed by Newton in the preceding paper, who says it "is largely occupied with the description of the retina and the structures to be found in the optic lobes of arthropods. It is extremely interesting to find that the peculiar oval bodies which Leydig figured from the optic lobe of *Dytiscus*, and were afterwards described and figured by me in the eye of the lobster are to be found in a more or less modified form in all the insects and crustacea described by Berger. The remarkable crossing of the nerve fibres between the retina and the lenticular bodies is seen not to be peculiar to the lobster. The brains of a number of insects are described, and in each of them the author seems to have found the homologues of the 'mushroom bodies,' although in some, e. g., the diptera, they are very rudimentary."

Our fellow member, Dr. E. L. Mark, has described[51] the nervous system of Phylloxera, correcting Prof. Riley's[52] description. The most striking peculiarity is the want of that concentration found in most of the plant-lice, there being two instead of one, post-oral ganglionic masses, the first of which is a flattened, rounded mass, connected by very stout and short commissures with the second, larger, heart-shaped ganglion, the point of which continues into a median nerve which, shortly, bifurcates. A good figure of the parts is given.

Mr. Jules Künckel emphasizes in a short note[53] the importance of the nervous system as a guide to classification of insects, and discusses the affinities of the different families of diptera on this basis, a matter with which we are not here concerned; but the fact that five families — *Stratiomyidae*, *Conopidae*, *Tabanidae*, *Syrphidae*, and certain acalypterous *Muscidae* — show a decentralization of the nervous system in the adult is very interesting. In these cases the ganglia, which are separated in the embryo, in the larva approach and coalesce, only to be again separated while in the pupal stage. Of the other diptera, some groups show the usual centralizing tendency with the development of the insect, and in others the ganglia remain in the same condition through life.

I have also a reference to a paper[54] by Mr. J. W. Slater on the nervous system, but I have not seen it.

New methods of preparation have given great impetus to the study of the eye, and we find several papers to record besides the independent work of Grenacher, already alluded to. Mr. B. T. Lowne is the author of one[55] on the modifications of the simple

[50] Arb. Inst. Wien, v. 1, p. 173.

[51] Psyche, v. 2, p. 201, Jan. 1879.

[52] Prof. Riley admits his error in this respect (Psyche, v. 2, p. 225). In the same note he combats Cornu's opinion that the mechanical action of the puncture and the subsequent absorption of liquid, can alone account for the development of Phylloxera, or other, galls.

[53] Comptes rend., v. 89, p. 491.

[54] The Entomologist, v. 12, p. 291.

[55] Phil. Trans., v. 169, p. 577.

and compound eye in insects. The former is believed to be of little use except merely in perceiving the intensity of light. The latter includes two radically different eyes: a true compound eye in the brachycerous diptera, the lepidoptera, orthoptera, and coleoptera; and the aggregate eye in the hymenoptera, nematocerous diptera, hemiptera, and many coleoptera. The details of structure are of course too complex to admit of an intelligible abstract. Müller's, or the "mosaic" theory of vision is regarded as the most probable, and Mr. Lowne's remarks on the sharpness of insect vision are most interesting. *Aeschna*, *Vespa*, and *Bombus* are supposed to see an object 20 feet distant, in the same detail as man would do at 160 feet, and this when the object is in the line of greatest sharpness of vision. *Tabanus* sees in the same way at 20 to 360; *Syrphus*, 20 to 1200, *Noctua*, 20 to 2400, and *Tipula*, 20 to 4800. In Mr. Lowne's view then, the insect eye is far from sharp-sighted, and if he is correct it would seem difficult to explain the delicate patterns of coloration by sexual selection, as has generally been done.

Prof. Grenacher's work leads Dr. V. Graber [56] to publish an important paper on the simple eye of the *Tracheata*, especially referring to spiders and myriapods, the latter group having been neglected by Grenacher. The cornea of the simple eye or *stemma*, shows the pore canals as well as the lamination of the rest of the cuticula. The crystalline body (hypoderm) is separated from the retina by a lamella, which is the extension of the inner cuticular membrane which underlies the hypoderm. This fact speaks against the hypodermic origin of the retina. The inner cuticula also extends downwards, clothing the whole retinal elements (*sclera*). The retinal segments are not single cells like those of the facetted eye, but show a basal ganglionic cell and a nucleated distal cylinder. The axial rod of the cylinder in *Buthus* seems to be a direct continuation of the ganglion cell, and so of an optic fibre. The stemma of *Buthus* is not a single optic element, but really a pentamerous compound eye.

Graber also points out the similarity between the auditory elements (in *Acridium*) and the optic elements are described.

Mr. Anton Stecker [57] finds that in the pseudo-scorpion genus *Chernes*, which is usually eyeless, some specimens possess rudimentary eyes. In *Chernes cimicoides* specimens were found with transparent spots in the position of the eyes in chilopods. To these spots an optic nerve proceeds from the optic lobes, but there is no trace of the crystalline rods. About 33 per cent. of the specimens were thus semi-eyed. The rest were totally blind, and wanted the optic nerves. The former class were offspring of seeing parents, while if either parent was sightless, the young were always so. With these most interesting discoveries, is added the fact that the optic nerve seems to send many of its fibres to the connective tissue under the epiderm, thus assuming another function.

Oscar Schmidt [58] in a short paper on the crystalline cone in arthropoda, discusses the mosaic theory of sight. His observations were mostly on the crustacea, a single paragraph refering to *Dyticus*, in the eye of

[56] Arch. Mik. Anat., v. 17, p. 58.

[57] Morphol. Jahrbuch, v. 4, p. 279.

[58] Zeitschr. wiss. Zool. v. 30, Suppl., p. 1.

which he succeeded in finding some obligue crystalline cones.

Graber [59] also describes an organ which he discovered in the antennae of several diptera, which he regards as auditory. This organ lies within the third antennal joint, on the inside and near the base. It is, briefly, a closed globular thick-walled, chitinous capsule, the wall being made up of rounded or oval plates, from each one of which springs interiorly a hair; a layer of epithelial cells surrounds the capsule, and outside of this a *tunica propria*. A large nerve branch runs to this organ, but the intimate connection between the elements of the two could not be made out. Graber thinks, as will be supposed, that the hairs vibrate to sound waves, and he sees nothing to indicate that the organ may be other than auditory. The ordinary hairs clothing the antennae, Graber shows, are in connection with special nerve elements, and are probably organs of touch.

Another singular organ Graber finds [60] in an unknown dipterous larva, and this, too, as it can apparently be nothing else, is thought auditory. It is situated under the dorsal integument, from which it is quite independent, at the junction of the ninth and tenth segments, and just behind the dorsal vessel. It consists of a pear-shaped sac, prolonged backwards into a fine tube, the end of which, lying in the terminal segment, unfortunately could not be demonstrated; but Graber thinks the sac and its tube represent an infolding of the integument. Two diverging muscles inserted on the sides of the eighth segment support the forward end, the sac being thus suspended by two anterior and one posterior (the tube) braces. Within the sac are eight black rounded bodies, borne on short stalks, and looking like so many berries. These bodies — the presumed otoliths — are hung in four pairs, one behind the other, thus giving a segmented character to the organ, which is still more apparent from the fact that the second pair, and the third and fourth — which are united together — lie in separate sacs within the first, like the coats of an onion. The organ is supplied with a nerve on each side, but nothing more definite could be shown. As to this larva, Dr. Hermann Krauss [61] states that it is the larva of *Tabanus autumnalis* L., and that Prof. Brauer pointed out the organ in question to his classes four years ago. Krauss affirms that it is o be found in the perfect insect, by the study of which its nature can perhaps be settled.

With regard to the supposed antennal otocysts of Graber, Dr. Paul Mayer in a letter to Carus' Zool. Anzeiger (v. 2, p. 182), states that these are by no means closed vescicles but are really wide-open mouthed sacs. Moreover that though only one is present in *Syrphus* and *Drosophila*, *Sicus* has at least three, and *Eristalis* a whole series, of them. Indeed, Mayer thinks the size of the third antennal joint stands in direct relation to the number of these organs borne on it. *Musca vomitoria* has nearly fifty, for example, which in this case have been described and figured by Leydig,[62] so that Graber cannot claim them as his discovery. Mayer believes them

[59] Arch. Mikr. Anat., v. 16, p. 36. Abstract, Journ. Roy. Micr. Soc., v. 2, p. 45.

[60] Ibid., p. 47.

[61] Carus' Zool. Anzeig., v. 2, p. 229.

[62] Müller's Arch., 1860, p. 276, pl. 8. They are also described in Mr. Lowne's monograph on the Blow-fly, London, 1870. This writer believes them olfactory organs.

probably sense organs, and has traced, in stained sections, nerve fibres into the hair-bearing hypodermic cells, but whether they are auditory or olfactory must be decided by future investigations.

Dr. Mayer has also published a longer paper,[63] with plates, on the same organs. The hairs in the vesicles are pale and transparent, with rounded tips, and the *cuticula* is also pale and delicate ; each hair belongs to a single cell, which sends up a process into the lumen of the hair. This is always the case, even in the small single-haired fossae. The observations of F. Berte,[64] on the antennae of *Pulex*, are criticized as very inaccurate.

Dr. G. Haller [65] describes the respiratory system of mosquito larvae. The lateral tracheal trunks end separately in the longer anal process. The shorter process has gills furnished with branches from one of the main trunks. In the terminal segments of the larva is also an air reservoir consisting of a number of fine tracheal branchlets, probably supplied by the second trunk. Hairs on the breathing tube are regarded as sensory, and connected with the terminal nerve ganglion. Other hairs on the body, including some resembling lepidopterous scales, are described. The breathing pore is provided with closing valves, but there is no similar arrangement in the pupal breathing horns.

Dr. Philip Bertkau in a paper [66] on a natural system of Arachnids, makes a few remarks on the tracheae of some spiders, figures of which are subjoined.

I have only found one reference to the circulatory system of insects, which is a short note in Carus' Zool. Anzeiger (v. 1, p. 274), by Dr. Béla Dezso, stating that in insects, myriapods and spiders, there are as many pairs of clefts in the dorsal vessel as there are pairs of stigmata.

Schmiedeknecht in a monograph [67] of the Thuringian species of *Bombus*, describes the male genitalia of each species, and he finds in them widely distinct specific characters. Five pieces are recognized in these organs, and German names proposed, but these seem in no way preferable to the latin nomenclature of Thompson.

The types of the external male genitalia of the European butterflies are described and figured by Dr. F. B. White,[68] whose paper will be of value to systematists. The apical segment, the dorsal element of which Dr. White calls the "tegumen," is wrongly regarded as the eighth instead of the ninth.

Besides the paper on the gizzard in ants already mentioned, Dr. Aug. Forel has published another important anatomical contribution [69] on the poison and anal glands of these insects. A careful description is given of the former, and of its modifications in different genera. According to the character of the poison reservoir the *Formicidae* are divided into two sharp groups, *Camponotidae* and *Dolichoderidae*. In the former, the reservoir is very large, and dorsally between its *tunica propria* and *intima* it is padded, so to speak, with the folds of an immensely long tube, simple or branching, which is probably a continua-

[63] Mem. R. Accad. Lincei. Roma, 4 maggio 1879.

[64] Ricerche Lab. Anat. norm. R. Univers. Roma, 1878, v. 2, p. 77–82.

[65] Arch. Naturg., v. 44, p 91.

[66] Arch. Naturg., v. 44, p. 351.

[67] Jenaische Zeitschr. Nat., v. 12, p. 303.

[68] Linn. Trans., s. 2, Zool., v. 1, p. 357.

[69] Zeitschr. wiss. Zool., v. 30, Suppl. p. 28.

tion of the tube in the poison glands, and which, after winding over the reservoir, finally opens into it. In the second group the reservoir is smaller, the homologous tube is short, and ends in a knob-like expansion in the interior of the reservoir. Moreover, the tube does not simply pierce the wall of the reservoir, but pushes it inwards, as it were, thus making for itself another envelope. The histology of the different parts is fully discussed, and many important general deductions are made. Besides the poison apparatus, Forel has discovered that the *Dolichoderidae* also possess anal glands and sacs, similar to those found in many insects, especially beetles. This anal sac lies above the digestive tract, and opens above the anus. Its secretion is probably mephitic, and recalls the secretion of Wolff's mandibular glands in the bees. The author believes that Wolff is greatly in error in regard to his supposed organ of smell in the bees, which have indeed little development of this sense. From simple experiments on *Polistes* the antennae certainly seem the seat of the organ in question.

The sting of the honey-bee is the subject of a short paper [70] by Mr. J. D. Hyatt. The hard parts and their mode of action are described, and illustrated by sectional and other drawings. Nothing new seems to be made out.

Two papers relating to the male and female reproductive apparatus of the cockroach, I have not seen. One, however, by Mr. Siegf. Brehm [71] appears to be written in Russian. The second [72] by Mr. Duchamp, treats of the structure and development of the egg capsule; a subject also noticed by Dr. H. Kadyi, in a note [73] on the egg laying apparatus of the cockroach. The sexual opening lies in a chamber — the vulva — formed by two shield-like processes of the seventh abdominal segment, and covered above by the anal segments. At the base of the vulva opens the vagina, a coecal, flattened tube, containing numerous chitinous structures, and among them three palpus-like organs. On the ventral vaginal wall is the common opening of the two oviducts; and opposite that of the *recept. seminis*, and of the two accessory glands, a large branched one on the left, and a small one, hitherto overlooked, on the right. These glands pour their secretion over the closed vulvar plates, to form the end of the egg case, which is thus a cast of the inner surface of the plates. As the eggs are placed in position, the end of the case is gradually protruded, until it contains the regular number — sixteen — one from each ovarian tube. The posterior directed end of the escaping egg is placed downward in the case, and the eggs from the right ovary occupy the left side of the case, and *vice versa*. The inner end of the latter bears the marks of the papillae which hold it, and thus differs from the outer end.

In concluding this review, I have only to say that I do not claim it as a complete record, but I hope to have given you a fair idea of the amount and character of the latest additions to our knowledge of insect anatomy.

Edward Burgess.

Boston, 9 Jan. 1880.

[70] Amer. Quart. Micr. Journ., v. 1, p. 3.

[71] Dissertatio Inaug., St. Petersburg, 1879.

[72] Revue Sc. Nat., Montpellier, v. 7, p. 423.

[73] Carus' Zool. Anzeig., v. 2, p. 632.